

Loss of Dynamic Aperture Due to Random Quadrupole Errors

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(1)

Why Should the random a_i, b_i affect Dynamic Aperture?

Random b_i , generates

Random a_i, b_i , ~~not~~ generate effects which make the particle go out to larger χ and γ in the magnets where the particle may see larger field errors due to random and systematic higher multipoles.

Random b_i , generates $\Delta B_x/B_x$, $\Delta B_y/B_y$ and $\Delta \gamma_p$

Random a_i , generates $\Delta B_1/B_1$, $\Delta B_2/B_2$

(B_1, B_2 are the β -functions of the normal modes) and $\Delta \gamma_p$

In $\Delta P/P \Rightarrow$, the important effects are

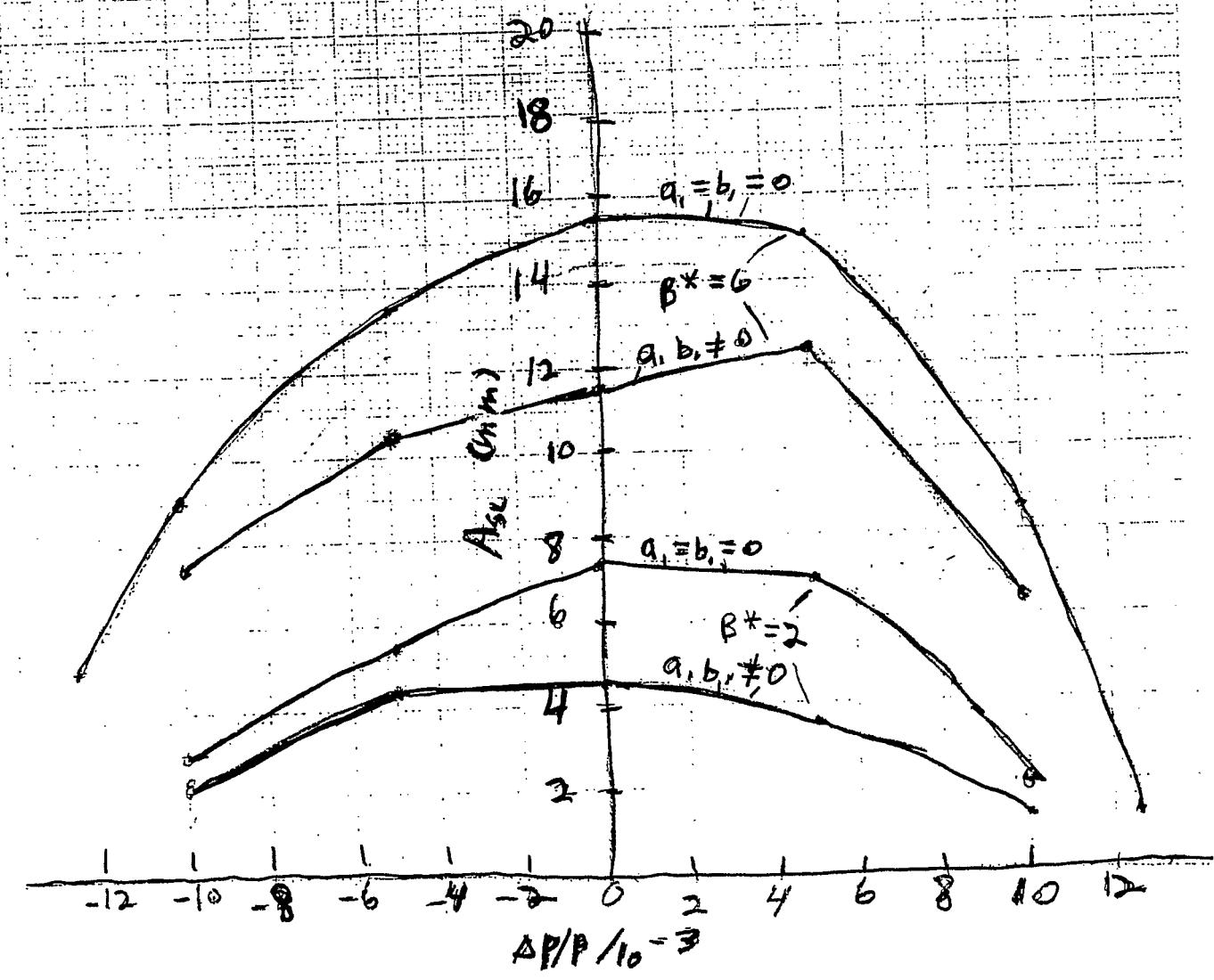
Random $b_i \rightarrow \Delta B_x/B_x$, $\Delta B_y/B_y$

Random $a_i \rightarrow \Delta B_1/B_1$, $\Delta B_2/B_2$

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A_{SL} including a_i, b_i

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A_{SL} definition + Results

worse case out of 10 machines.

Multipoles present - random a , b ,

random $b_k, k \leq 10$, systematic $b_k, k \leq 18$.

For $\beta^* = 6$, 2 machines out of 10 have

$$A_{SL} = 11.5 \text{ mm}, \text{ a loss of } 4 \text{ mm at } \delta p/p = 0$$

For $\beta^* = 2$, 1 machine out of 10 at $\delta p/p = 0$

$$\text{has } A_{SL} = 3.5 \text{ mm, a loss of } 3 \text{ mm}$$

For $\beta^* = 6$ at $\delta p/p = 0$, $\frac{1}{2}$ of the 4 mm loss in A_{SL} ,
 1 mm appears due to random b ,
 3 mm appears due to random a .

Quads and dipoles appear to cause about
 equal losses

The source of Asc Loss

The tracking results can be correlated with X_{MXT} , the largest Δx ⁱⁿ a particle reaches in the run at some particular class of magnets, like the QF and QD, in the high β quads. The ~~cells~~ with small A_{SL} , also give the largest X_{MXT} for the same initial x and y .

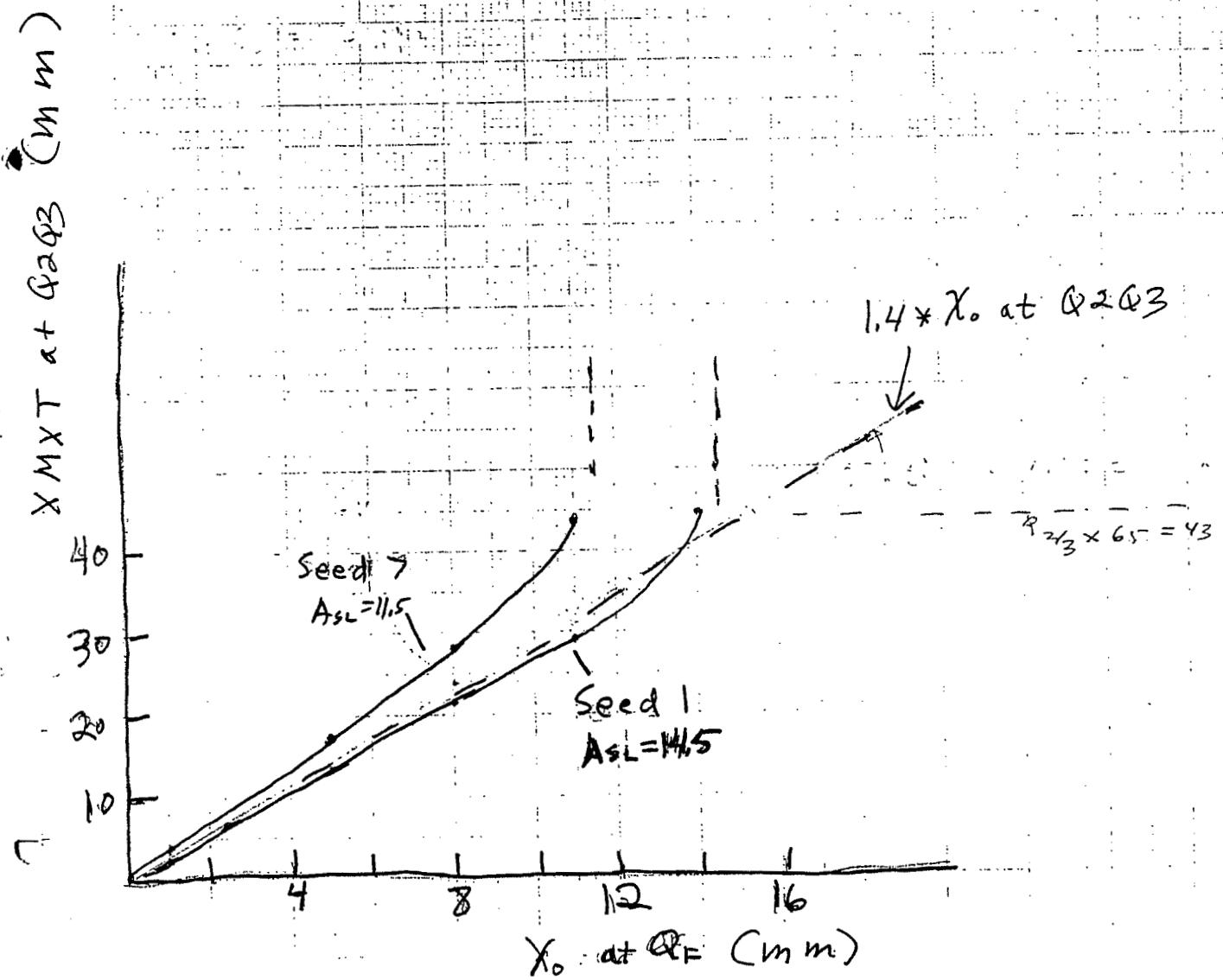
This X_{MXT} is ~~a~~ measure of the distortion ~~in~~ in the β functions due to a , and b .

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a, b, present
all bk present

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χ_{MXT} versus χ_0



The linear increase in χ_{MXT} with x_0 is consistent with the source being a β -function distortion. The increase in χ_{MXT} for the $N_{seed}=7$ case of about 30% over the $N_{seed}=1$ case indicates β -~~distortion~~ distortion of about 50% primarily due to the random a_1 .

Correction of the Loss in A_{SL}

Use the a_1 correctors in the arcs near QD, assuming independent excitation of all correctors. Set correctors so as to reduce χ_{MXT} . Compute A_{SL} for case that gives best correction of χ_{MXT} .

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Results of Correction

N _{seed}	Reduction in ΔMXT (mm)	Increase in A _{ISL} (dm m)
<u>B* = 6</u>		
7	43 → 30	11.5 → 15.5
8	41 → 34	11.5 → 15.5
<u>B* = 2</u>		
7	35 → 26	3.5 → 6.5

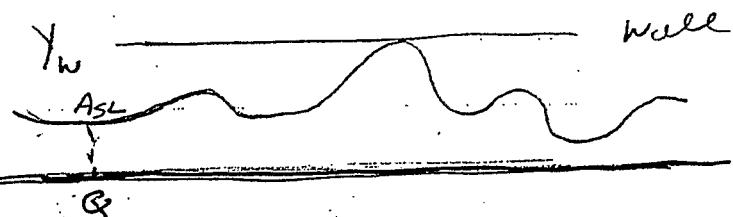
Maximum Correction Required $Q_1 = 4 \times 10^{-3} / \text{cm}$
over 1m.

Is the loss in aperture Real?

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Linear Field with Wall

$$\text{Acceptance} = \frac{\gamma_w^2}{\beta_{\max}}$$



Simple example

With a perturbation - assume $\Delta \beta / \beta = \pm .20$

$$\text{Acceptance} = \frac{\gamma_w^2}{\beta_{\max}}, \text{ reduced by } 20\%$$

At observation point Q, A_{SL} depends on $\Delta \beta / \beta$ at Q

If $\frac{\Delta \beta}{\beta} = 0$, A_{SL} reduced by 10%.

$\frac{\Delta \beta}{\beta} = .20$, A_{SL} unchanged

$\frac{\Delta \beta}{\beta} = -.20$, A_{SL} reduced by 20%.

Effective change in A_{SL} not easy to determine.

In our case, since the loss in A_{SL} is correlated with a distortion in the β -functions through an increase in χ_{MXT} of about 30%, a loss in A_{SL} of about 30% may be expected.

possible

Some Unsolved Problems

How well can one do with
just 4 families of α_1 / sextant?

What measurements can one do
to help set the correctors?

Can one correct the A_{SC} loss
and the residual $(Y_1 - Y_2)$
simultaneously?